

MORPHOLOGICAL SPECIFICS OF CRANIOFACIAL COMPLEX IN PEOPLE WITH VARIOUS TYPES OF FACIAL SKELETON GROWTH IN CASE OF TRANSVERSAL OCCLUSION ANOMALIES

Article history:
Submitted 20 April 2019
Accepted 28 June 2019

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ABSTRACT — Harmonious structure of the craniofacial complex is the major component for physical, mental and social well-being. Therefore, delayed diagnostics and treatment of dentoalveolar pathology may lead not to social maladjustment only, yet also to an increased risk of periodontal diseases, carious lesions, and temporomandibular joint functional issues. Following the outcomes of studies involving head anthropometric measurements, computed tomograms and lateral telerradiography of 68 people with physiological occlusion and various types of the facial skeleton growth, a method has been proposed, which can be employed to evaluate the facial structure balance, based on the match between the anteroposterior dimensions of the maxilla alveolar process and the mandible alveolar part. Only 76.47±5.14% of patients have been identified as having balanced ratios; 14.71±4.29% of the patients were found to have maxillary sagittal dimensions prevailing, with another 8.82±3.44% featuring the prevalence of the mandible anterior-posterior dimensions. Besides, the dominance of the mandible body dimensions in relation to the branch has been found in all types of growth of the head facial area. The obtained data have been compared with the anthropometric and radiological data of 12 patients with cross occlusion. It has been proven that in patients with cross occlusion, a change in the face configuration and the dental system morphological status depends on the anomaly shape as well as on the degree of the mandible transversal shift.

KEYWORDS — physiological occlusion; transversal anomalies of occlusion; type of head facial area growth; lateral telerradiography; cone-beam computed tomography.

INTRODUCTION

The prevalence of dental anomalies and deformities in Russia, which are leading among the maxillofacial issues, varies considerably in the range of 30.9–82.8%. The progressing growth of dentition malformations, leading to social maladjustment, increased risk of developing carious lesions, periodontal diseases, and temporomandibular joint (TMJ) functional disorders, demands the development and implementation of advanced and highly effective methods for dental pathology diagnostics and treatment [1–9]. Diagnostics of the dental system anomalies and deformations is based on the clinical examinations results and on additional (laboratory) data, while the treatment tactics for this group of patients depends on a whole set of factors, the leading ones being the type of pathology, the severity of changes, the stage of occlusion development (the patient's age) [10–21].

Orthodontic care in childhood (adolescence) implies creating favorable conditions for balanced growth, the development of the child's dental system and facial skeleton, which is achieved through eliminating bad habits and improving respective functions. In case of older age groups, this set of measures is expanded with orthodontic equipment, which is often combined with surgical interventions. Experts note that it is a combination of conservative and surgical treatments based on comprehensive diagnostics involving radiological and functional methods that allows achieving a morphological, functional, and aesthetic balance in the dentofacial system structure and functioning along with stable remote clinical outcomes [22–38].

Cross occlusion, related to the anomalies of dentition closure in the transverse direction, is one of the most complex issues entailing maxillofacial aesthetic, morphological and functional changes. The occurrence of cross occlusion among all dentofacial anomalies is not the same for different age categories — in children (adolescents) it is up to 1.9%, whereas in people of mature age it goes up to 3%. The following factors lay the ground for cross occlusion: jaw bones impaired growth due to inflammation issues; reduced chewing function or one-sided chewing with

early tooth extraction and multiple caries; changed sequence and timing of teething; uneven occlusal contacts and unworn milk teeth tubercles; improper swallowing; obstructed nasal breathing; congenital cleft palate; somatic pathologies caused by impaired phosphorus-calcium metabolism; traumatic injuries; disturbed myodynamic balance between the masticatory, buccal, temporal musculature and suprahyoid muscles; musculoskeletal system issues with organic or peripheral type genesis (scoliosis); dysplastic bone disease (osteopathy); osteochondral tissue systemic lesions [39–41].

A mismatch in size, shape and position of the jaw bones or dentition, which cause anomalies in the transversal direction, underlie the classification of cross occlusion types depending on the type of morphological changes leading to the anomaly: articular, dentoalveolar, gnathic. The prevalence of the articular type in case of cross occlusion goes up to 77% of all transversal anomalies. Each type of cross occlusion can be symmetrical or asymmetric, unilateral or bilateral. Depending on the morphological changes in the dental system, L.S. Persin (2004) identified three types of cross occlusion: palatal occlusion, lingual occlusion and vestibular occlusion. Clinically, cross occlusion is determined by the anomaly type (severity), the nature of the disturbances (uni- or bilateral), the degree and extent of the dentition junction disturbance, as well as the shape (skeletal or dentoalveolar) of the anomaly, and is manifested by the following facial signs: face asymmetry; disturbed face configuration; chin shift towards the lips; chin slope [42].

In the maxillofacial area, the following functional disorders are typical of all types of cross occlusion: TMJ dysfunction; disturbed chewing efficiency; bruxism; functional failure of the chewing muscles; impaired lateral movements and blockage of the mandible. The most serious changes in the TMJ structures are to be observed in case of occlusion anomalies in the transverse direction. Clinical experts consider articular crossbite as an independent nosological type, where the etiology is determined not only by the TMJ issues, yet also by the asymmetry of the jaws or their parts — abnormal position; misproportionate branches; impaired growth of the body and/or the mandible alveolar part [43–45].

Employing cone-beam computed tomography as an advanced, high-tech, precision method allows not only determining structural and functional disorders of the dentomaxillary system elements in a linear, three-dimensional format, yet also conducting precise and accurate morphometric examinations to diagnose and select proper treatment tactics for patients suffering from maxillofacial area pathologies [46–57].

Knowing the morphological and functional features of dental system alterations through cross occlusion will help improve the methods for differential diagnostics of occlusal disorders in the transverse direction; reduce the time spent on diagnostics; offer explanation for the choice of the plan and method of treatment for dental anomalies; prevent potential complications (relapse); ensure stable long-term results.

Aim of study:

to carry out a morphometric evaluation of the dentition status in people featuring different various facial area growth types with physiological and cross occlusion.

MATERIALS AND METHODS

The survey involved 68 people in their first mature age, with a full set of permanent teeth, physiological occlusion, as well as 12 patients with cross occlusion, comparable in terms of age and gender. Subject to the age-periodization scheme recommended by the VII All-Union Conference on Age Morphology, Physiology and Biochemistry (Moscow, 1965), the first mature age for males is 22–35; for females — 21–35. Patients with physiological occlusion were divided into three groups depending on the jaw growth type. Following clinical experts' recommendations, the jaw growth type was identified by the mandible angle size and Bjork total angle. Group 1 included 41 people (60.3%) with a neutral growth type; Group 2 was 8 people (11.8%) with a vertical growth type, while Group 3 included 19 persons (27.9%) with a horizontal jaw growth type. Clinical, X-ray studies were conducted in strict compliance with the ethical principles of biomedical research and obtaining voluntary informed consent of all patients. The developed and approved provisions were fully consistent with the basic ethical legal and regulatory documents required for conducting research with human participation (Nürnberg Code, 1947; World Medical Association Declaration of Helsinki, 1964).

X-ray research methods for the maxillofacial area involved cone-beam computed tomography and lateral projection X-ray diffraction. Computed tomography was performed on a PaX-i3DSC conical tomograph with FOV cephalostat (17×15 cm) (VATECH Global, South Korea). Processing, storage and export of the X-ray images involved the Ez Dent-i™ software, a multiplanar reconstruction and a three-dimensional (3D) reconstruction — using the Ez 3D-i™ tomograph software for 3D diagnostics; viewing the saved data with an importing option was performed using the Viewer™ software. The thickness of the tomographic

section was 1 mm, the reconstruction step was 1 mm, the rotation step — 1 mm. Of the entire variety of research methods, points and reference lines, the major guidelines were selected for identifying the size of the apical jawbone: the **A** point is the upper jaw apical basis or the projection of the medial upper incisor root apex on the alveolar process vestibular surface; the **B** point is the mandible apical basis or projection of the medial lower incisor root apex on the vestibular surface of the mandible alveolar part. The occlusal plane was identified following the generally accepted methods. The distal point was the apex of the chewing surface vestibular distal tubercle on the mandible second molar. The anterior (interincisal) point was located in the middle of the distance between the medial incisors cutting edges on both jaws.

To identify the jaws size in the sagittal direction, the occlusal plane was used as the main guideline. The front point for calculating the upper jaw sagittal size was taken in a constructive point at the intersection of the perpendicular to the occlusal plane, drawn from the subspinal **A** point. Similar action was performed for the lower jaw, from the supramental **B** point. From the distal side, a perpendicular was drawn for the upper jaw, running to the occlusal plane from the **TM** point located on the convexity of the upper jaw tubercle distal surface (tuber maxillae) of the infratemporal surface (facies infratemporalis). The distance from the anterior point (**A'**) to the posterior point (**TM'**) matched the sagittal size of the maxilla alveolar process. On the lower jaw, the distal point of the alveolar part was set at the intersection of the mandible angle and the occlusal plane bisector. The distance from the anterior point (**B'**) to the distal point (**Go'**) matched the sagittal size of the mandible alveolar part. Besides, on the computed tomograms there had been the supramental **B** point marked in the projection of the antagonist root top apex. The mandible plane ran through the most convex points of the mandible body lower surface. Then a tangent line was drawn to the lower jaw branch. The intersection of the lines shaped the angle of the lower jaw at the **Go** point (gonion). The top point of the mandible articular head was defined as **Cond** (condylion). Then, a perpendicular from the **B** point was drawn descending onto the mandible line, while the point obtained through crossing the lines was set as the **B''** point (Fig. 1).

Teleradiography in the lateral projection was performed on an X-ray machine Rayscan Symphony Alpha 3D (South Korea). The results were processed using the RayScanver. 2.0.0.0 software offering the options of receiving, processing and storing data in a DICOM 3.0 compatible format. Shooting features: sensor type — CMOS; resolution detector

— 630×1024 pixels; focal spot — 0.5 mm; voxel size — 140–230 microns; magnification — 1.3; time — 2–14 s; panoramic image size — 148 mm. The type of the facial area growth was identified by the mandible angle size, which was shaped by tangent lines to the lower edge of the mandible body and branch. The angle ranging within 119° to 123° corresponded to the neutral type of jaw growth. A decrease or an increase in the mandible angle pointed at the horizontal and vertical growth types of the facial area, respectively (Fig. 2).

Computer software SimPlant, Viewer™, Ez 3Dent-i™, Ez 3D-i™ allowed obtaining precision digital indicators without additional measurements, which significantly reduced the study time and increased the data gained through the study. The photostatic face photographs of the patients with cross occlusion, made in frontal and lateral projections, were used to identify the jaws location in the craniofacial structure. The key reference points were the pupillary line, as well as the perpendicular that was drawn to the pupillary line from the **N** point (*nasion*) — the aesthetic center line. A shift of the mental **Gn** point (*gnation*) was measured in degrees, between the vertical lines of the aesthetic center and the **N–Gn** line. Besides, the horizontal lines position was evaluated, in particular the line passing through the mouth corners in relation to the pupillary line. In case of non-parallelism of these lines, the angle of the labial line was identified. Photostatic side-projection images were used to perform a face analysis following Schwarz A.M. with identifying the profile angles, the location of the jaws in relation to the lines proposed by Kantorowicz A., Ricketts R.M., Simon P.W. and other professionals that are generally recognized in orthodontic practice. An orbital line and the aesthetic center line were also drawn on a computed tomogram in the frontal projection, which was required to evaluate the deviation degree for the chin point and the mandible angles symmetry. An analysis of the telerradiographies was performed subject to generally accepted techniques in front and side projections using a package of applied computer software (Fig. 3).

For statistical analysis of the results, the software products STATISTICA 8.0 and SPSS 22.0 (StatSoft, USA) were used. For each feature, the following were determined: the arithmetic mean value and the arithmetic mean error. To identify the significance of the difference between the averages from the counterlateral sides, Student's t-criterion was identified. To examine the significance of the differences between the mean values, the dispersions analysis (ANOVA) was used.

RESULTS AND DISCUSSION

When identifying the balance of the antero-posterior size of the maxilla alveolar process and the

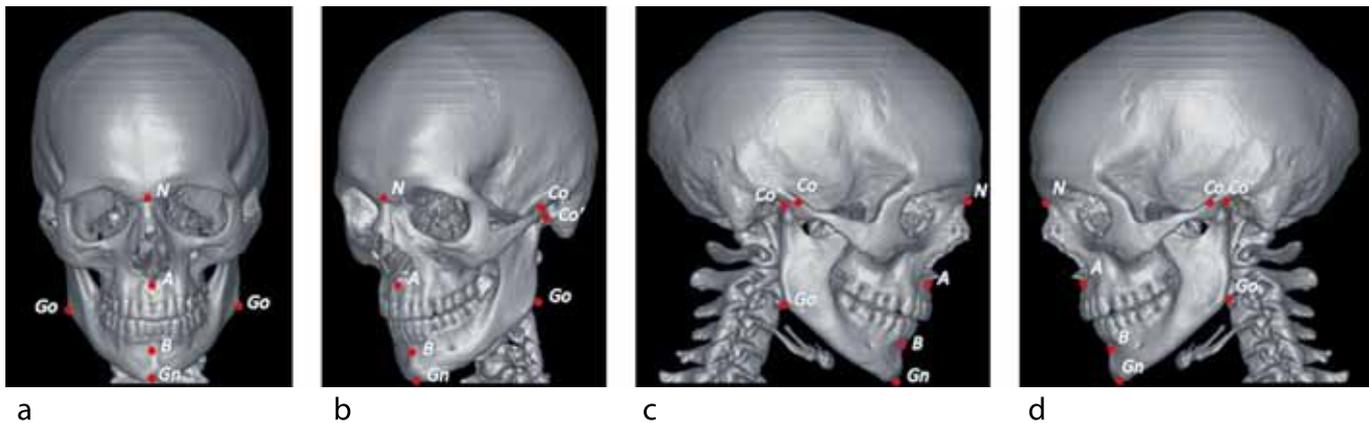


Fig. 1. Localization of points on a computed tomogram used to study the balance evaluation for the facial area structure: a — frontal; b — turning the head to the right by 3/4; c — lateral left projection; d — lateral right projection

mandible alveolar part, the lateral telerradiographies revealed that the $A'-TM'$ distance corresponded to the $B'-Go'$ length for 52 people of the studied group, which was $76.47 \pm 5.14\%$ of the total number of the participants involved. In 10 people ($14.71 \pm 4.29\%$), the sagittal sizes of the maxilla alveolar process exceeded those of the mandible alveolar part by an average of 2.87 ± 1.02 mm. At the same time, the antagonist teeth occlusive relations corresponded to the age and physiological norm and, as a rule, were observed in people with upper medial incisors physiological retrusion, at which the subspinal point A had an anterior shift. In 6 patients ($8.82 \pm 3.44\%$), the dimension of the mandible alveolar part was 1.95 ± 1.08 mm larger than the maxillary alveolar bone sagittal size, which, in our opinion, is due to the upper medial incisors physiological protrusion and the posterior shift of the upper apical basis (A point). As a result of the study, we proposed a method for identifying the balance of the mandible branch and body on the lateral telerradiographs.

Method description.

The mandible body sagittal dimension was identified from the Go point to the anterior point (B''), which was located at the intersection of the perpendicular built from the B point to the mandible plane. We suggested the vertical size of the branch be measured from the Go point to the Cond (condylion) point projection on the tangent line to the mandible branch. Taking into account the different scaling of telerradiographs, we used not absolute values of body length and branch height, yet relative indicators, defined as the percentage of the branch height to the mandible body.

In Group 1, the percentage ratio between the mandible branch and the body was $81.72 \pm 1.06\%$,

which means the predominance of the jaw body to the branch. In case of the vertical growth type, this ratio was $80.91 \pm 1.12\%$; with the horizontal growth type — $82.19 \pm 0.97\%$. An analysis of lateral projection telerradiographies revealed that the patients with the neutral growth type of the facial area had the mandible angle $120.73 \pm 1.18^\circ$. During that, the maxillofacial angle shaped by the intersection of the craniofacial and mandible planes was $43.51 \pm 2.87^\circ$. In people with the horizontal type of the face growth, the mandible angle was significantly smaller ($p \leq 0.05$), $108.93 \pm 3.62^\circ$ in the group as a whole. A significant decrease in the maxillofacial angle down to $36.61 \pm 2.17^\circ$ was also observed. The vertical type of face growth contributed to an increase in the angles up to $126.11 \pm 2.19^\circ$ and $51.24 \pm 1.22^\circ$, respectively, which can be seen from Fig. 4.

Table 1 offers a view on the results of examining the main angular parameters in the lateral telerradiographies in people with various types of the facial area growth.

Lateral telerradiographies angular measurements in patients with physiological bite revealed that regardless of the facial area growth type, the position of the jaw (upper, lower) in relation to the main anatomical and topographical craniofacial reference marks fell within the physiological norm.

There were no statistically significant differences detected in people with different facial growth types in terms of the ANS angle showing the location of the upper jaw in the facial skull, and the size of the BNS angle, which establishes the mandible orientation regarding the skull. The ANS angle parameters in people with physiological occlusion varied within $84-89^\circ$. The BNS angle was slightly smaller than the ANS angle,

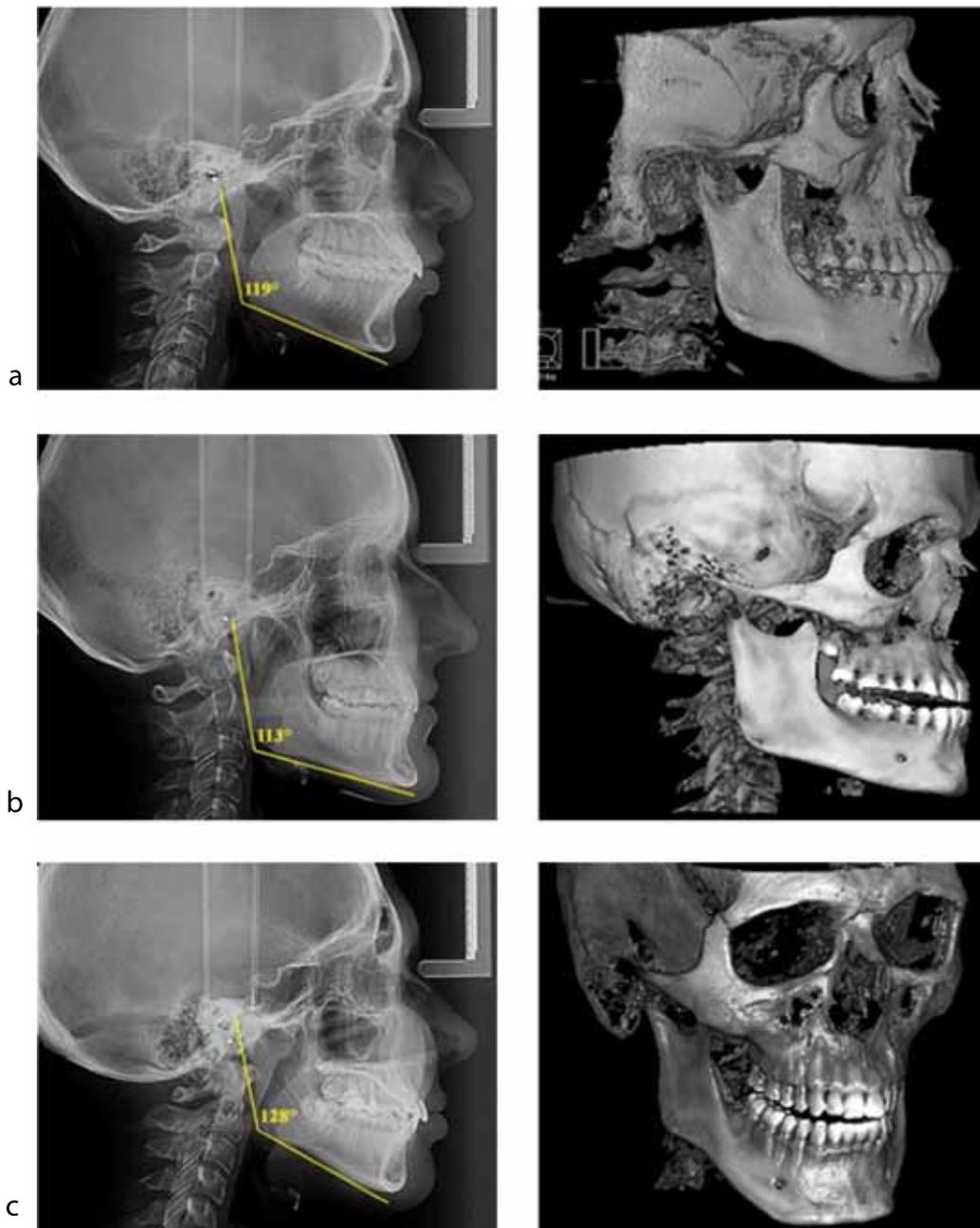


Fig. 2. The prominence of the mandible angle on computed tomograms and lateral teloradiographies with the neutral (a), horizontal (b) and vertical (c) types of the facial area growth

yet also did not depend on the facial growth type. The study outcomes showed that in people with different facial growth types, the fluctuation of the ANB angle indicators is 2–3°, while a slight increase in the angle is typical for people with the vertical growth type, and a decrease in the angle — for those with the horizontal type of facial growth. Of interest is the inconsistency of Bjork total angle with the tailored prescriptions

since for all the growth types its value was lower than what data from respective literature suggest. However, significant differences within the groups involved in the study, were identified. In people with the neutral growth type, the angle varied from 380° to 384°, with a decrease in the angle typical of people with the horizontal growth type, and an increase — for the vertical facial growth type.

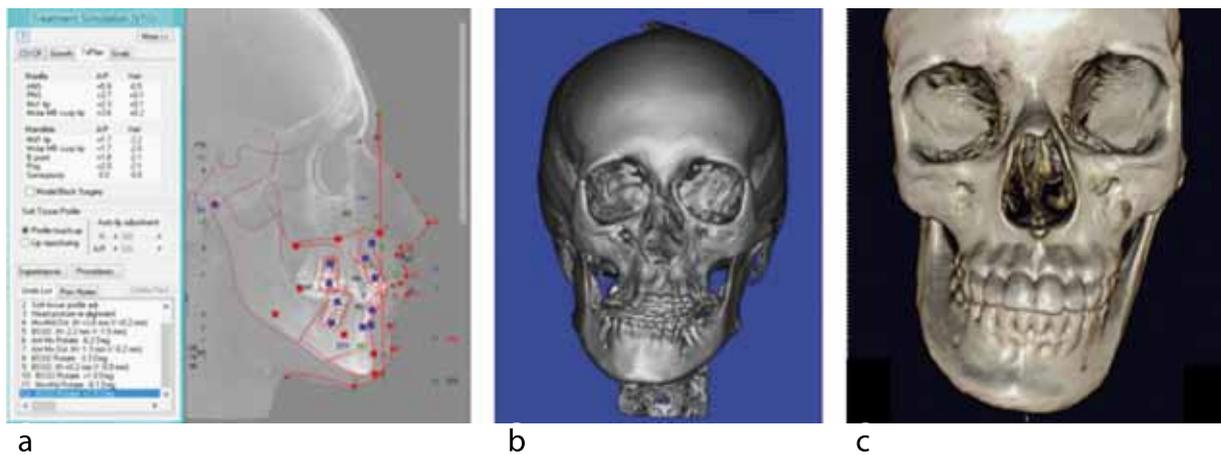


Fig. 3. Radiography image of a patient with cross occlusion in the lateral projection (a) and computed tomogram in the frontal projection (b, c)

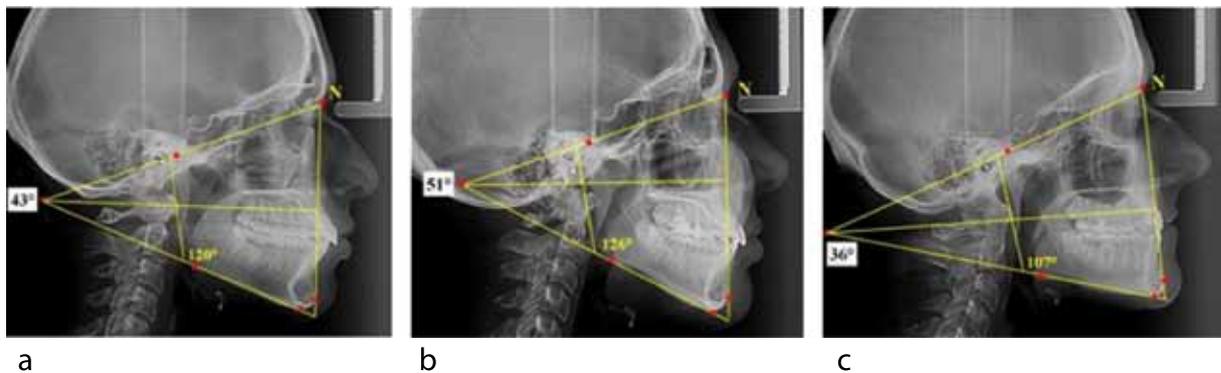


Fig. 4. Specific features of maxillofacial angle and mandible angle with neutral (a), vertical (b) and horizontal (c) growth types

Table 1. Lateral telerradiographies major angular parameters in people with various types of facial area growth (degrees), ($M \pm m$)

The parameters of radiographs	X-ray indices for growth type:		
	horizontal	neutral	upright
ANS angle	87,33±1,15	87,11±1,21	86,52±1,34
BNS angle	85,67±1,46	84,17±1,35	82,38±1,96
ANB angle	1,67±0,96	2,94±0,81	4,12±1,83
Ricketts angle	98,89±1,39	90,44±1,14	86,68±1,38
Bjork angle	375,33±1,27	382,06±2,06	388,53±1,67
N-Go-Me angle	64,33±1,26	71,61±1,98	79,15±1,82
Mandibular angle	113,22±0,84	120,07±1,24	127,65±1,68
OL-ML angle	9,02±0,88	15,04±0,48	17,52±0,51
NL-ML angle	19,78±1,92	29,39±1,75	36,48±2,87

Images of the oral cavity in the anterior projection in patients with buccal (a), lingual (b), buccal-lingual types of cross bite before and after orthodontic treatment (Fig. 5).

Clinical and laboratory examinations revealed that almost all patients featured a shifted mental *Gn* point (*gnation*) deviating from the aesthetic center line by 8–12°, depending on the pathology severity. The mouth angle on the shift side, as a rule, was elevated, while drawn down on the opposite side, whereas the line connecting the mouth corners converged with the pupillary line at an angle of 6–10° (Fig. 6).

Patients with gnathic cross occlusions typically featured a mandible angle different from that of people with physiological occlusion; the branch vs. body ratio did not meet the age norm, nor did it meet the gnathic and dental facial types (Fig. 7).

Virtually all the patients with cross occlusion featured a shift of the *Gn* mental point from the vertical line. Notable were the unequal mandible angles, while the tooth-containing parts, both in the maxilla and mandible, often matched each other (Fig. 8).

Further tactics and scope of complex orthodontic and surgical treatment, aimed at improving the jaws



Fig. 5. Images of the oral cavity in anterior projection in patients with buccal (a), lingual (b), buccal-lingual types of cross bite before and after orthodontic treatment

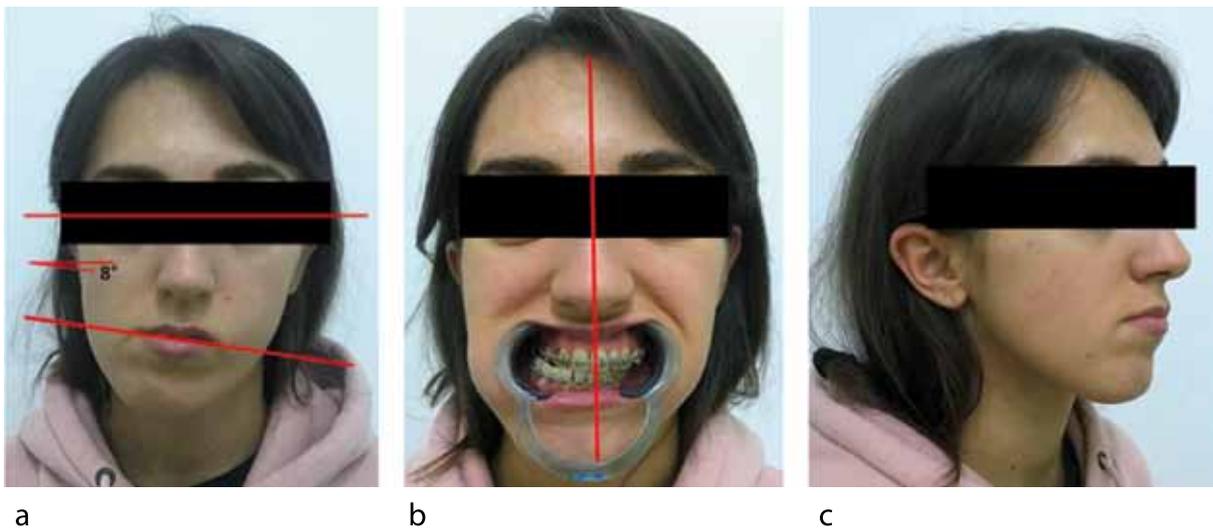


Fig. 6. Facial features in patient with cross occlusion in direct (a,b) and lateral (c) projections

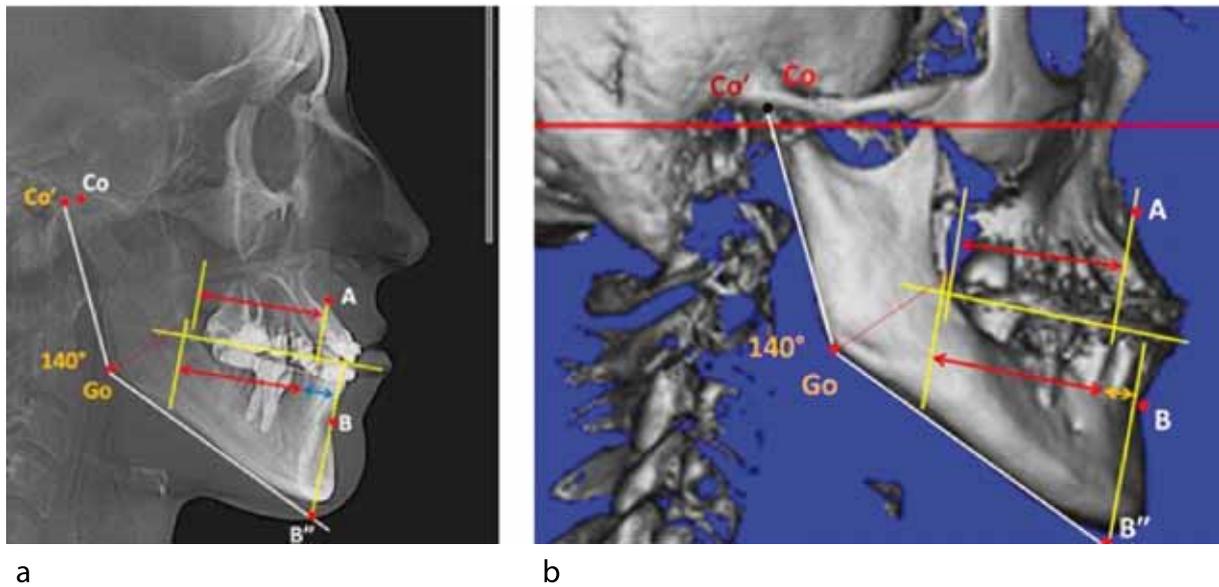


Fig. 7. Maxillofacial angle and mandible angle features in the lateral teloradiography and computed tomogram in sagittal projection in patient with cross occlusion

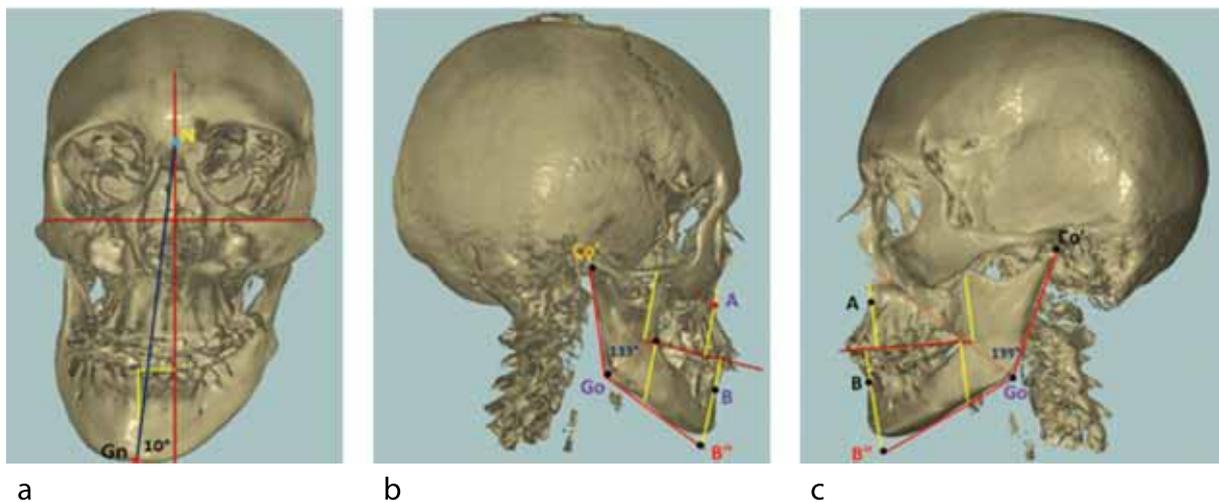


Fig. 8. The position of the mental Gn point regarding the vertical line (a); unequal angles of the mandible on computed tomogram in sagittal projection in patient with cross occlusion, right (b) and left (c)

size and position was developed via computer simulation in view of the maxillofacial pathology severity (Fig. 9).

Comprehensive treatment, as a rule, allows achieving a functional and aesthetic optimum for the maxillofacial area (Fig. 10).

After surgical treatment, orthodontic and prosthetic treatments were continued, aimed at improving the occlusal relations and certain morphometric parameters.

CONCLUSIONS

1. The most reliable and diagnostically significant indicator of all linear and angular parameters that determine the direction and type of the facial area growth is Bjork total angle, which, along with the lower gonial angle ($\angle NGoMe$), the front angle according to Ricketts ($\angle BaNPtGn$), the angel determining the position of the plane of the mandible base in relation to the anterior skull base ($\angle ML-NSL$), the maxillary angle ($\angle B$) and the ratio of the face posterior

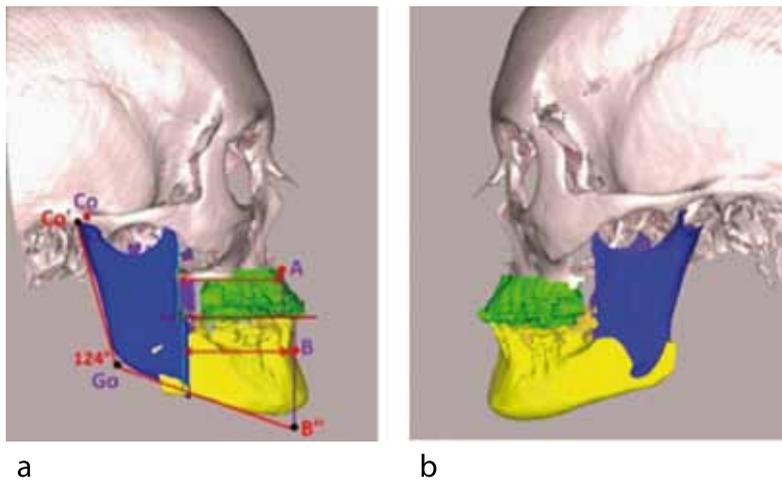


Fig. 9. Planning of surgical treatment for patient with cross occlusion, computed tomograms in sagittal projection, right (a) and left (b)

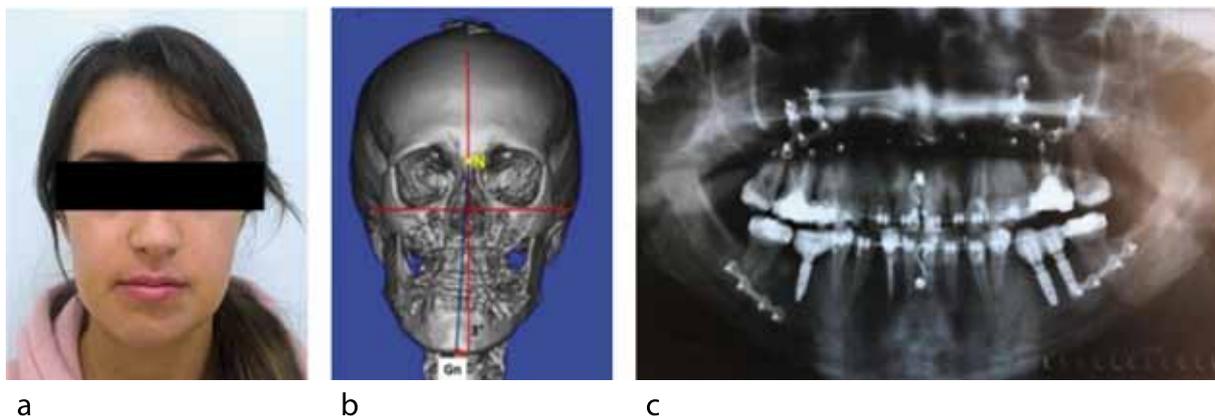


Fig. 10. Maxillofacial area after comprehensive treatment performed on patient with cross occlusion: a — improved facial features; b — reduced mental Gn point shift from the vertical line according to computed tomography (b) and x-ray outcomes (c) in direct projection

height to the face anterior height (SGo:NMe) allows an objective assessment of the facial growth types.

2. A method has been proposed for assessing the balance of the facial area structure, based on the match between the maxilla alveolar process anteroposterior size and the mandible alveolar part, calculated using the head lateral projection telerradiography patterns. We have identified that $76.47 \pm 5.14\%$ of the total number of the examined patients with physiological occlusion feature proportionate balance; $14.71 \pm 4.29\%$ of the patients had the maxillary sagittal dimensions prevailing, with another $8.82 \pm 3.44\%$ patients featuring the prevalence of the mandible anterior-posterior dimensions.

3. The data obtained through the analysis of the clinical & radiology method for detecting the mandible branch vs. body balance indicate that in

case of the neutral facial growth type, the size of the mandible body prevails (the mandible vs. body ratio is $81.72 \pm 1.06\%$). The dominance of the mandible body dimensions in relation to the branch was observed in case of the vertical ($80.91 \pm 1.12\%$ ratio), as well as at the horizontal ($82.19 \pm 0.97\%$ ratio) facial growth types.

4. Changed face configuration in patients with cross occlusion depends on the mandible transversal shift degree, and include the following set of disturbed facial features: chin shift away from the aesthetic center line ($8-12^\circ$); raised angle of the mouth on the shifted side, and lowered – on the opposite side; retracted upper lip on the shifted side; lower face flattening side opposite to the shift; the angle shaped by the line connecting the mouth corners and the pupillary line equals $6-10^\circ$.

5. The data from the head lateral telerradiographies and computed tomograms in patients with cross

occlusion indicate that the size of the mandible branch and body (shortening) on the shift side does not correspond to the age norm, as well as to the gnathic and dental face types. The mandible angle on the shift side approaches 90° (right angle), while on the opposite side it is 136–140° (developed angle).

6. Offering an accurate and reliable diagnosis, as well as planning a correct and rational orthodontic treatment for patients with cross occlusion, should take studying the head lateral telerradiographic patterns and evaluating the face skeleton growth type.

7. The inclusion of angular parameters that identify the direction and facial growth type in the «Clinical protocols for diagnostics and outpatient orthodontic treatment of dental and maxillary anomalies» will reduce significantly the time that orthodontists spend at the clinical examination and diagnostics stages; improve the efficiency of early diagnostics for transversal occlusion anomalies; prevent temporomandibular joint pathology development; ensure a stable prolonged effect of treatment while reducing the risk of long-term negative effects.

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